IMPLEMENTATION OF TEMPORARY STORAGE AT THE REMO LANDFILL SITE

Daneel GEYSEN

Group Machiels, Ekkelgaarden 16, 3500 Hasselt, Belgium

daneel.geysen@machiels.com

Abstract

This paper describes the implementation of Temporary Storage at the Remo landfill site in Houthalen-Helchteren, Belgium. Temporary Storage is an essential part of the Closing the Circle project. Closing the Circle will maximise the recycling of materials and/or recover energy from the landfill site. However, upon excavation, not everything can be directly used in the production cycle. On or off-site treatment is required to get valuable products. For several waste streams, no such treatment technology is available yet or the market is not yet ready to accommodate the recycled products and/or the mass to be treated is too low to allow economic recycling. Collecting more mass of similar quality, further develop technology and the market will make sure that these wastes become resources. The management of such a temporary stock is part of 'Temporary Storage'. The implementation of Temporary Storage at the Remo landfill site will demonstrate how such storage can be organised. It will also demonstrate how, during storage, action can be undertaken to recover materials in-situ. The technology is applicable for fresh waste as well as for materials from landfill mining.

Introduction

Group Machiels is fully committed to transform waste into resources. It operates the Remo landfill site which is already for a long period addressed as a 'storage site' where materials are brought together in view of later valorisation, as discussed by Hoekstra *et al.*[1] and Jones *et al.*[2] In line with the regulation, Industrial Waste (IW) at the Remo site were stored separately from Municipal Solid Waste (MSW) and in double protected cells if that was required. Gas was extracted from MSW and used for power and heat production. This gas production is now slowly coming to an end. The time is ready to start safe mining and several excavation and valorisation tests have been executed.[3]

The excavation tests quickly demonstrated the heterogeneity of materials dug up from the landfill site. Valorisation of such materials requires intensive separation and after that not all materials can be directly recycled:

1. the quality is much too low compared to the requirements of the current market;
2. no technology is available yet for upcycling and/or no technology is available at the moment to use this inferior quality for materials production;
3. the technology is available but the scale of the operation does not yet allow to generate a profitable business case.

Improving recycling for these waste streams requires to tackle the three challenges being: technology, market and scale of operation. The timing for recycling/recovery of materials that are disposed will depend on these three elements. 'Temporary Storage' can provide the required time to develop technology, develop the market and obtain sufficient materials to operate at an interesting scale. Temporary Storage will allow to store resources up to 'the time of excavation' in such conditions that loss of quality is limited. Ideally, the time of storage is used to improve the quality or partly recover materials or energy.[1]

Firstly, development of recycling technologies for wastes that are currently still disposed, is ideally already taking place at the production facility. Such developments will at least result in lower landfill costs for fresh waste. However, they would have much more impact and success if they are also applicable to landfilled waste and take into account the possibilities provided by Temporary Storage. In fact, such developments should benefit from the interplay of the different stages of the materials life cycle of which Temporary Storage is just one stage. The resulting technology should deliver an interesting business opportunity and should bridge the gap between waste and resource. Such developments require an active push, certainly for the innovative *in-situ* technologies acting on the waste during storage (see further).[1]

Secondly, there is no business for a process without a market for its products. Hence, more efforts are required to create markets for recycled materials. This is unfortunately recently demonstrated for plastics for which the market in China almost completely disappeared as a result of the Chinese Green Fence Campaign.[4,5] The campaign is in fact in line with Europe's interest to prevent resource export, certainly to countries with poor recycling conditions.[6] However, the attitude of Europe to criticise countries like China because of the environmentally unfriendly recycling technologies is much too easy. Instead, Europe should strengthen its own market for recycled products if it wants to take serious action related to its resource policy and life cycle thinking. Only then will companies invest in Europe in innovative technologies. It is too easy to stop thinking of a market for all recycled materials because the current quality is much too poor compared to that of primary resources. Technology and products should be developed at the materials production side that can cope or accommodate the quality of recycled resources which can be inferior to that of primary resources. The required innovation should thus not only target the recycling industry but also the materials production industry. This is fully in line with life cycle thinking and the value chain approach set forward by the European Commission.

Thirdly, the scale of operation will affect the business plan of a waste to resource transformation. Temporary Storage can help in providing the appropriate amounts coming from one or more producers.

It is clear from the above that 'Temporary Storage' cannot only be applicable to fresh waste (that still needs to be landfilled) but also the non-recyclables from landfill mining. There is, however, a difference between them. For fresh wastes going to the landfill, huge separation efforts could be saved at the 'time of excavation', if the method of collection, delivery and storage would be improved. Already upon the collection of waste it can be highly mixed. In addition, discharge and further spreading and compaction on the landfill increases the degree of mixing. Indeed, stability was and still is a main concern resulting in the mixing of waste off-site but also on-site to improve the structural stability and accessibility of the landfill. Off-site mixing is performed in specialised and permitted plants in which sludges or pastes are mixed with binders to obtain a minimal compressive strength. On-site mixing consists of combining structurally strong with more soft materials to allow for example trucks driving on the site. For landfilled materials, not all fractions upon separation can be directly recycled. Temporary Storage provides an outcome for these waste streams.

Wante[7] and Krook *et al.*[8] indicated that the concept of a landfill as a Temporary Storage site for waste materials awaiting recovery at some identified time in the future is not existing in the current legal framework. The naming 'Temporary Storage' is used in the EU Landfill Directive for storage in view of transportation or in view of recovery in which case the storage is limited to 3 years.[7,1] In all other conditions, the Landfill Directive considers the activity as traditional landfilling. A legal framework for the longer storage in view of later (longer than 3 years) recycling/recovery still needs to be created. The naming 'Temporary Storage' is in that respect maybe not well chosen. '*Temporary stock*' as indicated by Wante[7] or 'Transitory Storage' as suggested by Hoekstra *et al.*[1] sound like good suggestions, albeit that the problem of correct naming and other regulatory issues should not hamper this innovative development.[9]

Group Machiels was granted a permit to set up a Temporary Storage site where almost 1,2 million m^3 of materials can be collected between 2014 and 2017.

Meanwhile, Group Machiels is developing a permit for landfill mining of the same site, starting in 2017. The latter permit comprises not only the excavation operations but also several transformation techniques of which the basis is the separation with materials recovery and gasification of calorific non-recyclables to syngas and the conversion of syngas to hydrogen and methane. These gasses can be either re-introduced in the materials production cycle or may become the future energy carriers.[10]

Group Machiels will apply and further develop separate storage and *in-situ* landfill mining techniques, as described by Hoekstra *et al.* in this volume.[1] The operation will take in to account all precautionary measures as indicated by Wante,[7] Krook *et al.*[8] and Hoekstra *et al.*[1] and will be conceived as a traditional landfill because specific regulations for Temporary Storages do not exist yet. All developments such as described by Hoekstra *et al.*[1] (in-situ remediation, flushing, extraction *etc*.) will follow a step wise approach starting from lab scale testing, pilot scale testing, demonstration and finally full scale implementation to avoid any environmental risk and to be in line with the current environmental permit.

This paper describes the setup of the Temporary Storage at the Remo site in Houthalen-Helchteren and the approach of the step wise developments such as *in-situ* remediation, flushing and *in-situ* extraction. This Temporary Storage is part of the Closing The Circle (CtC) landfill mining project of Group Machiels.

Temporary Storage at Remo

Figure 1 illustrates the different developments in time of the Remo landfill site within the CtC project of Group Machiels. It shows the current landfilling activities (C. Actual Situation), the landfill mining and resource recovery operation (B. Closing the Circle) and the future re-established nature area (A. Nature Reserve). Indeed, the final goal of the project is not only to maximise the recycling/recovery of possible resources but also to re-establish as much nature as possible.[3] The Closing the Circle stage itself consist of several phases. Establishing Temporary Storage is the first phase (see Figure 1). The Temporary Storage operation will start before the mining and transformation to resources for which the permit will be granted later. This not only provides continuity of operations at the Remo site but will, in time, allow the development of this crucial and necessary element of Enhanced Landfill Mining, which has been defined as "*the safe conditioning, excavation and integrated valorisation of (historic and/or future) landfilled waste streams as both materials (Waste-to-Material, WtM) and energy (Waste-to-Energy, WtE), using innovative transformation technologies and respecting the most stringent social and ecological*

Figure 1: The different phases of the landfill mining operation at the Remo landfill site.

criteria".[11] Temporary Storage is a crucial technology for those streams that do not have direct valorisation opportunities upon excavation and separation (lack of technology, market, right scale of operation, see above and Hoekstra *et al.*[1]). Several techniques related to Temporary Storage should be ready at the start of the excavations and will become incorporated in the mining and transformation activities and as such in the permit. The period of Temporary Storage prior to the mining activity will also provide extra material of which at least a part can be used almost directly in the separation and transformation technologies. This allows that these technologies have potential access to an 'easier' input in the beginning of their operation.

The second phase of the CtC stage will consist of a demonstration plant to bridge the gap between the current existing scale of innovative technologies and the scale required for the full scale operation of CtC. It will consist of separation technology and a plasma gasification process.[12] During this demonstration phase, the final uncertainties and questions related to technology, products and markets need to be addressed by operating on an already industrial scale. The outcome will allow the building of the full scale CtC in phase 3. The previous phase will each time become incorporated in the next phase. Figure 2 shows the site where the Temporary Storage will be organised. The size of the area is 89 ha providing space for 1.200.000 m^3 of waste materials.

In line with Hoekstra *et al.*, Temporary Storage at the Remo site will consist of *ex-situ* and *in-situ* landfill mining.[1] Materials available for *ex-situ landfill mining* will be

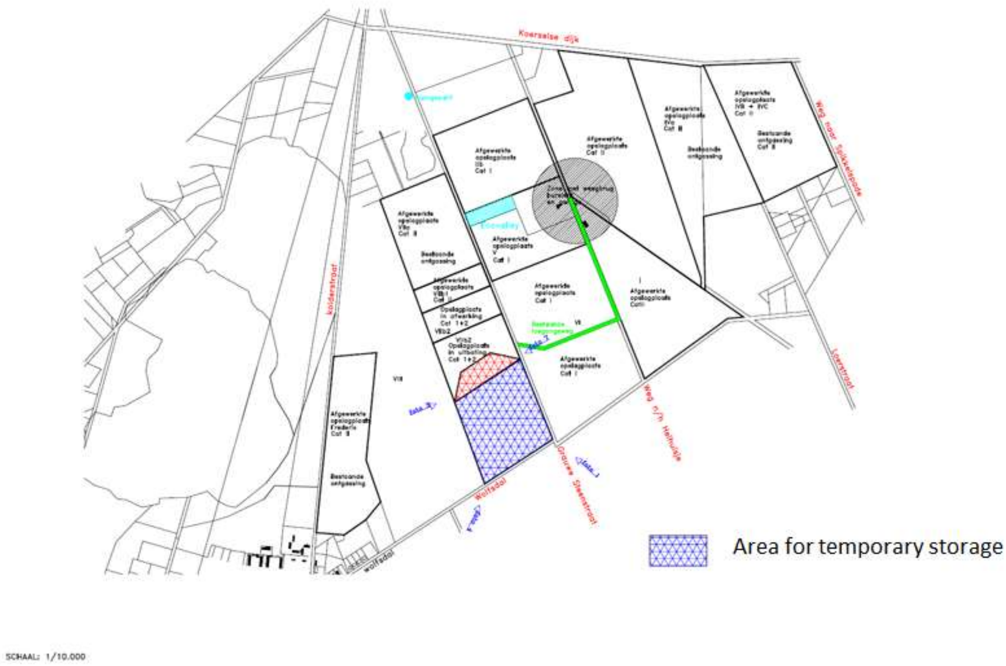

Figure 2: Remo landfill site with in blue the area where Temporary Storage will be organised.

stored as such that the excavation and additional treatment that is required because of the landfilling, will run smoothly without significantly increasing costs. Comparable waste streams will be stored together to increase the amount to be treated by the same or similar technology. Materials available for *in-situ landfill mining* will be treated/cleaned during storage to remove/destroy the remaining contamination and/or extract valuables such as metals.

Construction and organisation

For Temporary Storage, delivery and excavation in bulk is by far the easiest and cheapest method. Considering that the storage can be performed relatively dry, storage in bales does not provide much advantage. Today, it is mainly performed in waste and materials recycling activities to reduce space for transportation. On a bigger scale, in landfill operations, compactors are used. Baling, such as indicated by Hoekstra *et al.*[1] can, however, be beneficial to separate materials from others and keep it dry. Up to now, it is too expensive compared to bulk handling with an additional operational cost varying from 5 to 30 euro/tonne. In case of CtC, the separate storage of materials is of course limited by space and the daily organisation and variation in delivery does not allow to create a multitude of separate storage cells. This could be organised differently if more space and a guaranteed delivery (on long term) would be available. Thus, grouping materials is required which in this case is based on the current vision on potential valorisation routes being in general a route based on organic properties and a route based on inorganic properties. In both cases special attention is given to metals. Metals have on the one hand a potential economic interest but on the other hand bring along a potential environmental concern. Recycling options related to organic properties are the recycling of plastics such as PE, PP, PVC and several others.[14] Alternatives are the production, by means of pyrolysis or gasification, of the building blocks of chemicals and plastics such as monomers or even smaller (syngas, methane, carbon, hydrogen *etc*.).[12,13] The recycling paths related to inorganic properties (except metals) are up to now less clear and are mainly linked to building and construction applications. However, also within the group of building and construction materials there is increasing interest in materials with specific chemical composition to produce products such as various inorganic insulation materials and binders.[15]

The selective storage will be organised following three principles being:

1. Partitioning in bigger groups for which valorisation as a group is possible. This grouping forms the basis of the division of the Temporary Storage site in cells;
2. Generation of daily or weekly bigger uniform amounts which will be loaded in the corresponding cell to which the materials belong;
3. Registration of the location of materials and generation of a 3D model.

The following cells will be created for the partitioning of the bigger groups:

1. Carbon based – non-metal containing;
2. Carbon based – metal containing (metallic or other);
3. Non-carbon based – non-metal containing;
4. Non-carbon based – metal containing (metallic or other);
5. Asbestos containing building and construction elements;
6. All streams requiring storage in separate salt cell conditions.

Figure 3 gives an impression of how such division would look like. Each cell has a separate percolate collection system and is separated from the other cells by means of a 'wall'-like construction made from another clearly distinguishable and easy to separate material. The build-up of protection layers, drainage system and leakage detection is similar to that of a landfill.

The above construction and organisation addresses *ex-situ landfill mining.* Excavation and on-site or off-site technologies are required to perform separation and the generation of products such as recyclable plastics, metals, glass and/or SRF.

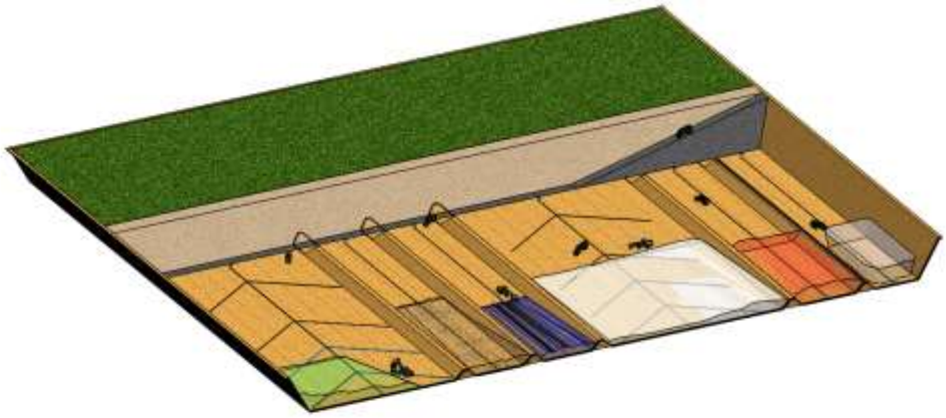

Figure 3: Visualisation of the organisation of the Temporary Storage site showing different cells and drainage system.

In-situ landfill mining

In a later stage of development also *in-situ* mining will be implemented. Possible *in-situ* actions are described by Hoekstra *et al.*[1] The three main *in-situ* techniques identified to be applicable to the CtC project are:

1. Extensive In-situ remediation (soil cleaning) to remove pollutants;
2. Flushing to remove soluble compounds;
3. Extraction to recover metals.

Hoekstra *et al.* describe the potential of further degrading pollutants and bio-degradable organics during Temporary Storage.[1] In case of CtC, bio-degradation and the production of methane is already performed on the Municipal Solid Waste fraction landfilled in the past. No fresh biodegradable waste is landfilled at the Remo site. All fresh waste that is currently landfilled has a TOC content < 6 wt%. In practice, the TOC content of materials currently landfilled at the Remo site is even lower and mainly limited to pollutants. Further degradation of the present TOC content is similar to *in-situ* soil cleaning techniques. The advantage of performing such action at the Remo site is the available time as indicated by Hoekstra *et al.* and the existing measures to protect the environment (impermeable layer with leakage detection, drainage system, pumping wells and waste water treatment plant). It allows to perform *extensive in-situ remediation*. The action consists of providing the ideal conditions for further breakdown of the organics by providing air, water, nutrients or chemicals (oxidation or reducing media) if required. Hoekstra *et al.* classified the time required for such action to be between 3 and 10 years. In the final full scale CtC project, methane production can still be obtained from organic rich fractions produced by the CtC separation and cleaning processes of landfilled materials. It can also be applied on the resulting product of one of the other *in-situ* technologies such as flushing or extraction to remove for example metals and/or soluble compounds (Cl^-, SO_4^{2-}, Na^+, K^+, …) that would otherwise prevent micro-organisms from growing.

Examples of materials that can be treated by *in-situ* remediation techniques are the many polluted soil and sludges, residues of cleaning operations of soils and sludge or fines from landfill mining operation. Such materials can contain elevated concentrations of mineral oil and other organics. Although several papers and patents describe activation of bio-degradation in landfills and technology for aeration of landfills, there are not many example yet of *in-situ* remediation of soil or sludge like materials in Temporary Storage conditions.[1,16,17,18,19] Therefore, lab scale tests will be performed first and later scaled up for demonstration. The CtC landfill mining permit will take into account the possibility to perform such actions on full scale. Lab scale tests will start first by degradation testing. This will identify the potential for further breakdown of pollutants. Secondly, permeability tests will identify the way of operation to overcome preferential channelling and the necessity for mixing the waste with other materials to enhance the permeability. Thirdly, the best conditions for breakdown will be defined. Alternating wetting and contacting with air is a potential technology which can be performed following several flow regimes and circulation directions. The full scale implementation will look similar to the setup of bioreactors as indicated in Figure 4.[20]

The set up consist of a reaction cell and the possibility to blow air and recirculate leachate with intermediate water treatment if required. In principle, the design allows to extract gas from the reaction cell. However, in case of the Remo Temporary

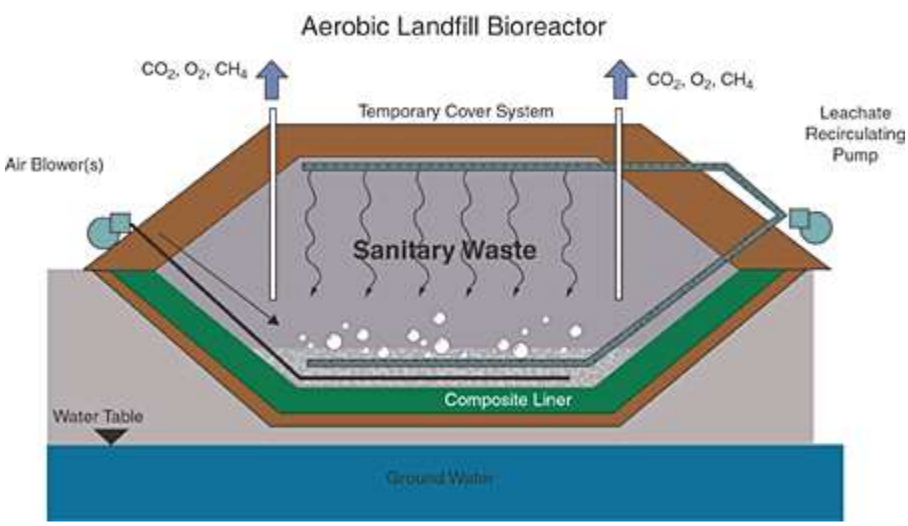

Figure 4: Schematic drawing of an aerobic landfill bioreactor, a setup which is similar to what is planned for cleaning of materials at CtC.[20]

Storage, the permit does not allow to accept material with a high Total Organic Content (TOC) content (see above). Gas extraction will thus be minimal in the Remo case. The set up allows the addition of other chemicals.

The second technology described by Hoekstra *et al.* that is applicable to CtC is *flushing*. Flushing aims to remove soluble compounds such as Cl^-, SO_4^{2-}, Na^+, K^+ *etc*. Also here, several flushing regimes taking into account the permeability of the material are possible. As indicated above, flushing can be combined with extensive *in-situ* remediation in which the flushing removes soluble compounds but also results in wetting to enhance biodegradation. The result of flushing is a material with decreased content in soluble compounds. The soluble compounds are ideally concentrated in the flushing medium to increase the water treatment efficiency and to reduce the amount of liquid required for flushing. It is, however, clear that removing soluble compounds is without any relevance if the flushing medium containing soluble compounds requires intensive cleaning and if the residues of such an operation need to be treated and landfilled. Technology needs to be further developed to produce soluble containing concentrates that can be used as a resource by other processes. An example of a flow scheme is given by Hoekstra *et al.* in this volume.[1]

The third technology, *extraction*, is much more close to hydrometallurgy. More aggressive media will be used to leach metals. The technology is similar to heap leaching and bio-leaching. Both technologies are applied on large scale for low grade ores. The technology, the use of liners and also the time of operation is similar to what is available by Temporary Storage. An example of the setup of heap leaching of metal containing ores is shown in Figures 5 and 6.

The use of more aggressive leaching media is new for traditional landfill technology and its permits. It is clear that this requires supplementary attention for environmental safety and the safety of employees. More experience is required and therefore, also here, first lab scale tests will be performed, which will be scaled up in steps before implanting the technology in full scale.

Lab scale testing will consists out of materials characterisation, batch pH-variation testing with various acids and/or complexing agents, column leaching test (down-flow and up-flow), the use of different liquid to solid (L/S) ratios and other variables. Modelling will be performed in combination with characterisation results in order to understand leaching behaviour. Also other techniques that enhance leaching will be studied including the use of micro-organisms.

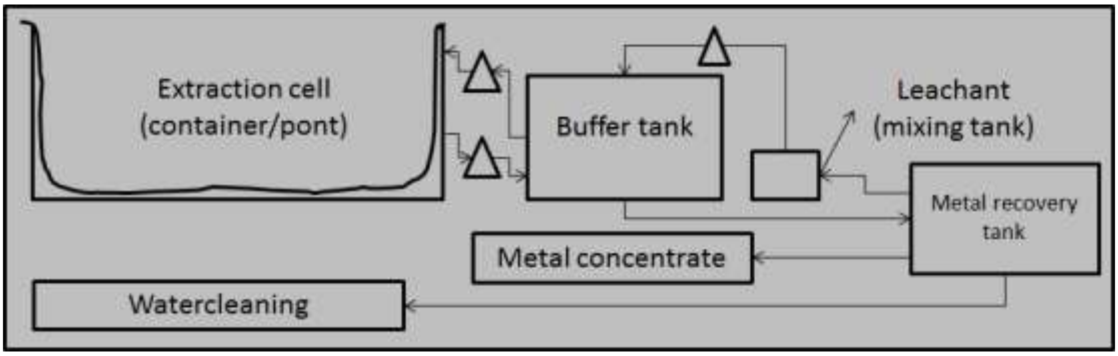

Figure 5: An example of a set-up for demonstrator scale *in-situ* metal extraction.

After lab scale testing, a lysimeter test of approximately 1 m^3 will be set up in all three cases. Subsequently a 30-60 m^3 test will be constructed in the field, by means of a container or a basin to demonstrate the technology on a larger scale. An example of such demonstrator setup for metal extraction is shown in Figure 5. The extraction cell (container or basin) receives leaching liquid from a buffer tank. The buffer tank also serves as the concentrator from which a fraction is continuously pumped to the metal recovery vessel, which can serve as precipitator or electrowinning cell or a combination of other techniques to recover metals and produce concentrates. The acidic solution can be recirculated to the extraction cell.

Several waste materials available at the Remo site contain metals in concentrations of several percentages (Ni, Cu, Pb, Zn *etc*.). The leaching liquid will contain a mixture of these metals. The lab scale test will identify which materials can be used for *in-situ* extraction.

A schematic drawing of heap leaching for ore extraction is shown in Figure 6. In this case solvent extraction and stripping is used before electrowinning to generate the concentrate. Several other options are possible. The goal is to produce a concentrate that can be further treated by other companies. To what extent the extraction will be performed at the Remo site will depend of the concentration and purity required by the actors on the market being able to use it as a feed in their materials production process. Note that a rubber liner is used in the drawing of Figure 6. Thiel *et al.* describes the several types of leach pads that exist for *in-situ* leaching and describes the use of liners to collect the leach solution.[21] An image of a lined area for Cu extraction is shown in Figure 7. The use of such liner is similar to that of a landfill. Thiel *et al.* indicates that typically, 1,5 mm HDPE, LLDPE or 0,75 to 1,0 mm PVC is used as liner material for ore extraction. The size of the grains in case of heap leaching of ores is much bigger than what we envisage to use in Temporary Storage. This will significantly influence the permeability. The height of the bed is, however,

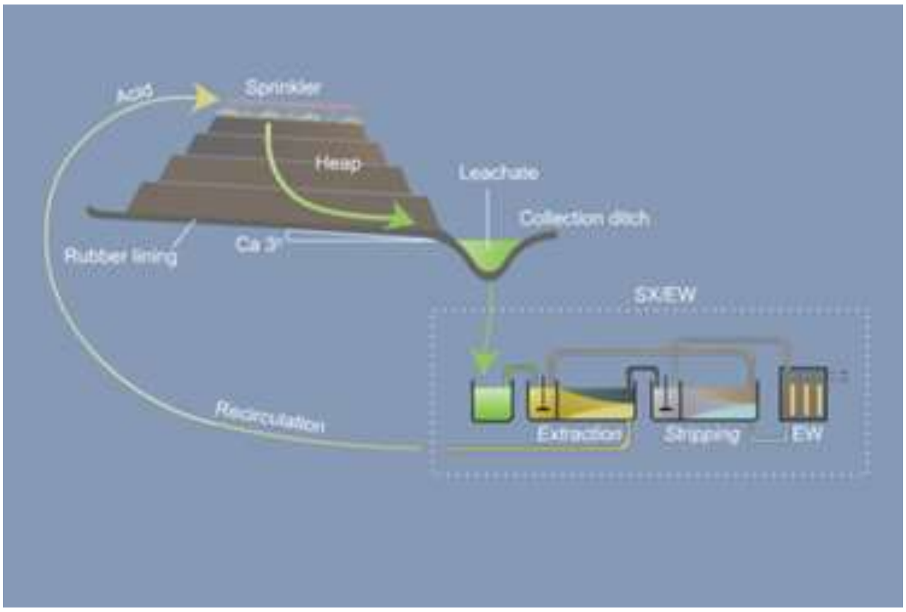

Figure 6: Schematic drawing of heap leaching after to Anna Bauer, BioMineWiki.[22]

much smaller than in case of ore extraction, reducing the risk for liner failures as discussed by Thiel *et al.* Further studies and tests will define which liner is preferred and whether or not leaching from the top to bottom is possible.

Figure 7 shows a case, in which an area of up to 150 ha with a valley shape is used for a leach pad able to contain 100 million tonnes of ore. The heap is leached from the top. The CtC scale for *in-situ* metal extraction will of course be much smaller but the example shows that the use of liners is similar to that of a landfill and that technology is available to perform such extractions.

Figure 7: Lined area for copper ore extraction after Thiel *et al.*[21]

Monitoring

Besides Group Machiels also the Flemish Public Waste Agency (OVAM) will monitor the development of Temporary Storage during the first phase of the Closing the Circle project. The monitoring will consist of a 3 monthly reporting of activities. The main topics of the monitoring are described below.

Valorisation potential

The assessment of the valorisation possibilities for the different waste streams that cannot be recycled yet will be performed by measuring the distance between the current situation and the implementation of new technologies. It considers an economic assessment of valorisation and an evaluation of the environmental impact of such new technologies. Such an assessment requires a strong interaction with technology providers, customers of the Temporary Storage and other actors in field of recycling. The methodology to perform such distance measurement still needs to be developed. This will ideally consist of a combination of an economic assessment, Life Cycle analysis and a forecast on the evolution of technology and market.

Separate storage

This part of the monitoring allows to follow up the quantities of waste delivered to the different cells of the landfill together with the exact cell and material position. Based on the results, it is concluded whether or not the size of a cell needs to be adapted. The waste to be delivered at the site will get a cell allocated in advance. The truck delivers the load to the corresponding cell. Every month, the amounts delivered to each cell, the used surface area and volume will be reported. Therefore, GPS coordinates of the waste fronts will be recorded and a 3D-model of the Temporary Storage constructed. The model provides the exact location of the different cells together with the description of the materials stored in it. The report will also include a description of the methodology or the material used to perform the separation between two different cells. Besides the information about the different cells, also the position of large individual waste streams within a cell will be recorded.

The description of the wastes finally stored in the different cells and that where it was designed for, is the basis of the assessment of the practical performance of the distribution in the cells. The height of the layers will be recorded to build the 3D-model of the Temporary Storage. The (technical and economic) potential of various packaging techniques are continuously assessed.

In-situ landfill mining

In-situ landfill mining will be monitored by reporting the results of the different phases (lab, lysimeter, demonstrator and full scale) of the three identified *in-situ* technologies.

Quality monitoring of stored materials

It is not clear yet whether the wastes that will be accepted on the site can degrade in some way due to which the quality and potential value decreases over time. An inventory will be made of such degradation processes and the monitoring methodology will be defined. Fire monitoring by using camera-technology becomes standard practice. Another degradation mechanism can be leaching of metals in case of a waste stream having an interesting content of metals. Controlling leaching can be performed by assessing the quality of percolate.

Conclusions

The paper described the setup of a Temporary Storage at the Remo site. The setup takes into account that the current Temporary Storage should comply with the regulation of landfills. The findings of this first Temporary Storage project will allow to create appropriate regulation.

Besides developing a legal framework for such temporary stocks/storage, the regulator can significantly contribute to the further development of the Temporary Storage technology in view of later valorisation. The regulator can apply various tools for the innovation and success of Temporary Storage similar but going further than the successes currently achieved for several clean and fresh waste streams such separately collected glass, paper, building and construction materials *etc*. As indicated earlier, this is at least as challenging as current separate collection schemes and introducing the recycled products thereof in the market. Each waste stream, currently disposed, needs to be looked at in detail and technical, market and legal barriers need to be solved. An example of such a waste, and probably the most difficult stream, are polluted soils and sludges.

The waste/materials authority can activate financial means for R&D activities by promoting research and demonstration in the field.[10,23] The authorities can participate in such activities by directly providing financial support, by applying landfill tax fees for R&D, demonstration and implementation of technology to transform stored waste into a resource.[10] The regulator can promote the cooperation between the various actors in the materials cycle.

Looking at the bigger picture, Temporary Storage is an element contributing to the transition towards Sustainable Materials Management (SMM) and is thus part of current waste and materials policy.[7,24] Temporary Storage is an attempt to make resources from materials that we consider as final waste. It is almost by definition that the more close we come to the state of 'final waste', the more difficult the innovation and the more challenging recycling and recovery becomes. However, bridging the gap between the state of 'being a waste' and becoming a resource for these challenging wastes is key to the success of a full SMM approach.

All wastes are materials and it should be clear that Temporary Storage is a management approach. It requires measures to be taken in order to allow creating resources from final wastes. The actions required during Temporary Storage to turn waste into a resource can be influenced and thus enhanced by actions taken in the preceding phases of the life cycle. As such, Temporary Storage scores much higher in the life cycle approach of resources, materials and waste compared to for example traditional waste incineration even if recovery of energy is included in the latter.

Acknowledgements

The author wishes to thank the several colleagues of Group Machiels working on the Closing the Circle (CtC) project including the Temporary Storage part of CtC. Many thanks to Hans Oonk (Oonkay) for the several technical discussions on the potential and implementation of *in-situ* technologies. Many thanks also to Nanne Hoekstra (Deltares) and Hans Groot (Deltares) for the inspiring meetings and discussions on Temporary Storage. These meetings will continue to take place and result in innovation on the field. Group Machiels is grateful for funding by Agentschap voor Innovatie door Wetenschap en Technologie (IWT), grant 100517 "Closing the Circle & Enhanced Landfill Mining as part of the Transition to Sustainable Materials Management".

References

1. N. Hoekstra, H. Groot, "Temporary Storage: a catalyst to enable landfill mining", in *Proceeding of the Second International Academic Symposium on Enhanced Landfill Mining*, Edited by P.T. Jones, 14-16 October 2013, Belgium.
2. P.T. Jones, D. Geysen, A. Rossy, K. Bienge, "Enhanced Landfill Mining (ELFM) and Enhanced Waste Management (EWM): essential components for the transition to Sustainable Materials Management (SMM)", in *Proceeding of the First International Academic Symposium on Enhanced Landfill Mining*, Edited by P.T. Jones and Y. Tielemans, 4-6 October 2010, Belgium.
3. Y. Tielemans, P. Laevers, "Closing the Circle, an Enhanced Landfill Mining Case study", in *Proceeding of the First International Academic Symposium on Enhanced Landfill Mining*, Edited by P.T. Jones and Y. Tielemans, 4-6 October 2010, Belgium.

4. K. Earley, “Could China’s ‘green fence’ prompt a global recycling innovation?”, The Guardian – Guardian Sustainable Business, 27 August, 2013.
5. S. Borad-Patawari, “Opportunities and Challenges in Plastic Recycling Industry”, *International conference and exhibition on commercial markets and options for end of life plastics*, 4-6 June 2013, Cologne, Germany.
6. K. Lundgren, “The global impact of e-waste: Addressing the challenge”, International Labour Office, Programme on Safety and Health at Work and the Environment (SafeWork), Sectorial Activities Department (SECTOR), Geneva, ILO, 2012.
7. J. Wante, “A European Legal Framework for Enhanced Waste Management”, in *Proceeding of the International Academic Symposium on Enhanced Landfill Mining*, Edited by P.T. Jones and Y. Tielemans, 4-6 October 2010, Belgium.
8. J. Krook, N. Johansson, P. Frändegard, “Potential and conditions for mining the technosphere”, in *Proceeding of the Second International Academic Symposium on Enhanced Landfill Mining*, Edited by P.T. Jones, 14-16 October 2013, Belgium.
9. Vlerick Business School, “Duurzaam Materialenbeheer en (voormalige) stortplaatsen. Een idee voor de vuilbak of toch maar recycleren?”, Resultaten van de Future Search workshop, 20 juni,, 2013.
10. Mc Kinsey, “A portfolio of power-trains for Europe: a fact-based analysis”, 2011.
11. P.T. Jones, D. Geysen, Y. Tielemans, S. Van Passel, Y. Pontikes, B. Blanpain, M. Quaghebeur and N. Hoekstra, “Enhanced Landfill Mining in view of multiple resource recovery: a critical review”, *Journal of Cleaner Production*, **55**, 45-55 (2013).
12. R. Taylor, C. Chapman, A. Faraz, “Transformation of syngas derived from landfilled waste using the gasplasma® process”, in *Proceeding of the Second International Academic Symposium on Enhanced Landfill Mining*, Edited by P.T. Jones, 14-16 October 2013, Belgium.
13. S. Hayward-Higham, “End of life plastics in the circular economy”, International conference and exhibition on commercial markets and options for end of life plastics, 4-6 June 2013, Cologne, Germany.
14. N. Hunton, “Closing the loop: turning the supply chain into a supply cycle by mining plastics from end-of-life durable goods”, International conference and exhibition on commercial markets and options for end of life plastics, 4-6 June 2013, Cologne, Germany.
15. J. Spooren, M. Quaghebeur, P. Nielsen, L. Machiels, B. Blanpain, Y. Pontikes, “Material recovery and upcycling within the ELFM concept of the REMO cases”, in *Proceeding of the Second International Academic Symposium on Enhanced Landfill Mining*, Edited by P.T. Jones, 14-16 October 2013, Belgium.
16. R. Goeschl, EP 0564434, Arrangement and procedure for the odour stabilisation of waste dumps, 1992.
17. R. Stegmann, *et al.*, DE10005243, Verfahren zur abgestuften beschleunigten in situ-Stabilisierung von Deponien und Altablagerungen, 2001.
18. M. Hudgins, US6364572 - Aerobic landfill bioreactor, 2002.
19. G. Layton, *et al.*, US2003108394 - Aerobic bioreduction of municipal solid waste landfill mass, 2003.
20. Aerobic Landfill Bioreactors, Center for Environmental Biotechnology, CEB website, internet, latest access August 2013 (http://esd.lbl.gov/ceb/landfill).
21. R. Thiel, M. Smith, “State of the practice review of heap leach pad design issues”, Geotextiles and Geomembranes, 22 (6) 555-568 (2004).
22. Anna Bauer, Heap Leaching, BioMineWiki, internet, latest access August 2013, (http://wiki.biomine.skelleftea.se/wiki/index.php?title=Image:HeapLeaching.png).
23. W. Annaert, “Policies for future material management cycles and Enhanced Waste Management”, in *Proceeding of the First International Academic Symposium on Enhanced Landfill Mining*, Edited by P.T. Jones and Y. Tielemans, 4-6 October 2010, Belgium.

24. E. Paredis, W. Tempst, J. Moyersoen, "Developing Enhanced Landfill Mining as a transition experiment: context, framing, methodology, questions", in *Proceeding of the First International Academic Symposium on Enhanced Landfill Minin*g, Edited by P.T. Jones and Y. Tielemans, 4-6 October 2010, Belgium.